STUDIES ON RADIATION LEVEL AND RADIOLOGICAL HAZARDS IN THE ENVIRONS OF UDUPI ON THE SOUTH WEST COAST OF INDIA

A Synopsis of the Ph.D.Thesis
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For the award of the degree of
DOCTOR OF PHILOSOPHY IN PHYSICS

Submitted by
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SYNOPSIS OF THE DOCTORAL THESIS

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Studies on Radiation Level and Radiological Hazards in the Environs of Udupi on the South West Coast of India

Introduction

Radioactivity is the emission of ionizing radiation or particle caused by spontaneous disintegration of atomic nuclei. The ionizing radiation originates from both natural and man-made sources (UNSCEAR, 2010). Radiations from the natural origin come from cosmic rays and radioactive nuclides in the earth's crust. Cosmic ray particles refer to both primary energetic particles of extraterrestrial origin that strike the Earth's atmosphere. The primary rays consists 85% of protons and 14% of alpha particles, with small amount of heavier nuclei (<1%). The rays which are produced by interaction of the primary rays and atmosphere, it consists of large number of subatomic particles such as pions, muons and electrons as termed Secondary cosmic rays. At sea level, the secondary Cosmic ray flux consists of 68% of muons and 30% of electrons with less than 1% of protons. The trans-continental flight determined an effective dose of about 0.5 mSv per round trip (NCRP, 1975). The production rate of radionuclides and particles varies appreciable with both altitude and latitude but relatively constant with time (Perkins and Nielsen, 1965). The cosmic ray is usually very stable at the earth surface but it does vary with geometric altitude above sea level. The absorbed dose rate in air in outdoor from cosmic radiation at sea level is about 30 $nGyh^{-1}$(UNSCEAR, 2000).

Exposures due to natural radiation are of particular importance because it accounts for largest contributor to the total collective radiation dose to the world population (UNSCEAR, 2000). Many radionuclides occur in terrestrial soil and rock and in building material derived from them. Upon decay these radionuclides produce an external radiation field to which all human beings are exposed. In terms of dose the principal radionuclides are ^{232}Th, ^{238}U and ^{40}K. Both ^{232}Th and ^{238}U head series of radionuclide produce significant exposure. The decay of naturally occurring radionuclides in the soil produces a gamma-beta radiation field in the soil that also crosses the soil-air interface to produce exposure to humans through ingestion or inhalation. The wide spread interest in the subject of environment has resulted in acceleration of research on the behavior of trace substances including radioactive materials in

the environment. Radionuclides are generally released in trace quantities to environment. They are then physically transported in the air or water media in which they are located.

The major contributors to the background radiation are ^{238}U, ^{232}Th and their decay products. Uranium -238 is the head of a series (4n+2) of 15 principal radionuclides. It is the most abundant (99.28%) isotope of natural uranium and is found in all rocks and soil with varied concentration, Uranium enters the atmosphere mainly due to the resuspension of the dust particles from the earth. It also enters the human food chain from the environment. The measured values of ^{238}U in bone of adults who live in areas of normal dietary levels are in the range of 50- 150 mBq kg^{-1} dry bone with an average activity of 50 mBq kg^{-1} (UNSCEAR, 1988). The radionuclide^{238}U decays to ^{226}Ra, an alpha emitter with a relatively long half-life of 120 years. Radium-226 and its daughter products constitute an important part of natural radiation exposure.

The radioactive members of ^{232}Th series contribute to the terrestrial background radiation significantly. The ^{232}Th radionuclide are found in soil and rock in varied proportion. ^{232}Th radionuclide with half-life of 1.4×10^{10} years, decay to form ^{228}Ra, with the emission of an alpha particles. ^{228}Ra is found in greater concentration in regions with monazite ores. The ^{228}Ra is readily available to plant and animals. The presence of ^{228}Ra in human is mainly due to intake through food chain and not due to decay of ^{232}Th in the human body. ^{220}Rn is a radioactive isotope of ^{222}Rn in ^{232}Th series has a half-life of 55 seconds.

The radionuclide ^{40}K is a singly occurring radioactive isotope, found in rocks and soil which contributes to terrestrial radiation with a half-life of 1.3×10^{12} years, has an abundance of 0.0118% in the environment. The crustal concentration of ^{40}K in the environmental matrices is higher in comparison with other singly occurring radionuclides. The specific activity of ^{40}K is 855 pCi gm^{-1} (Eisenbud,1987). Hence, the radiation dose contributed by ^{40}K is significant. ^{40}K may undergo beta decay to form ^{40}Ca radionuclide. On other hand ^{40}K may get transformed to ^{40}Ar, through K-electron capture. The excited ^{40}Ar nuclide comes down to ground state through gamma emission.

Ra-226 decay by alpha emission it transform to ^{222}Rn(Radon) a radioactive gas which is produced continuously from the natural decay series of ^{238}U.Radon is heaviest natural decay series of ^{238}U.Radon is heaviest naturally occurring radioactive noble gas having half-life of 3.82 days. Radium in soil is the main source of radon in the atmosphere. The radon reaches to the indoor spaces and outdoor atmosphere due to its penetration through structural

material and earth surfaces (Nazaroff and Nero, 1988). The major sources of radon in atmosphere are form emanations from soil that derived from rocks. Radon escapes more easily from the rocks through the openings. It also enters through groundwater. However, considerably higher radon levels can occur if radon is released into contained air spaces such as mining and milling industries and houses. The sand mining of Thorium and Uranium rich sands for minerals like rutile, zircon, ilmenite and monazite which have high amount of ^{210}Rn and ^{222}Rn.

The ^{210}Po and ^{210}Pb are lower radionuclides, formed with successive decay of members of ^{238}U series. ^{210}Po is found in varying concentration in sand, soil and naturally occurring water. The ^{222}Rn emanated from the earth surface decay to form ^{210}Po and ^{210}Pb radionuclides present in atmosphere. Some of the other sources of ^{210}Po and ^{210}Pb are burning of coal in coal-fired power plants (Daish et al., 2009). ^{210}Po is found in various environmental matrices, in partial equilibrium with ^{210}Bi and ^{210}Po. The equilibrium between ^{210}Pb - ^{210}Bi - ^{210}Po are influenced by chemical, biological and other factors. Hence the equilibrium between these radionuclides is partially reached (Jaworowski, 1967). ^{210}Po and ^{210}Pb radionuclides enters human body through food chain. ^{210}Pb is a bone seeker and hence gets accumulated in bone minerial.^{210}Po gets distributed on soft tissues after intake through food chain or inhalation.^{210}Po ($T_{1/2}$= 138 days) radionuclides emits an alpha particles with 5.3 MeV energy hence ^{210}Po causes greater biological damage when compared with beta emitting ^{210}Pb (Parfenov, 1974).

The radionuclides present in the environment can enter into plant by uptake from soil through root and by direct absorption through aerial part of plants. The former depends on the total amount of radionuclide in soil, on its chemical form and physico-chemical factors in the soil. The latter depends on the rate of radionuclide precipitation from the atmosphere and on the foliar retention. While some radionuclides are taken up as homologous of essential elements according to the metabolic requirements of the plant, other radionuclides are taken up irrespective of their biological necessity. The essential elements for the growth and reproduction of vegetation the natural radioactive element like uranium and thorium and their decay products (Linsalata, 1994). Leaves are the major parts of the plant and accumulate several kind of radionuclides through dry and wet deposition. Lichen, moss and few kinds of epiphytic orchids have a tendency like ^{210}Pb, ^{210}Po and ^{137}Cs from atmosphere. Plants depend on atmospheric moisture and dust particles for their nutrients, as a result the radionuclides which are attached to the dust particles are absorbed and get accumulated on these plants over

a period resulting in higher level activity. Moss and lichens are considered as natural bio-indicators in the environment since they have great affinity to accumulate ^{210}Pb and ^{210}Po and fission products (Heinrich et al. 1999).

In addition, some of the present day technological activities involve enhanced natural radiation exposure to the human population. The major pathways which lead to the enhanced radiation exposure are burning of coal in thermal power stations and the use of phosphate fertilizers in agriculture. Coal contains trace levels of natural radionuclides and its combustion results in their release into the environment mainly due to the escape of fly-ash in the atmosphere. The release of these radionuclides causes an enhancement in the ambient radiation fields in the immediate human environment. On the global scale it is estimated that about 5,000 tons of uranium and 8,000 tons of thorium are distributed along with their daughter products solely by coal combustion (Baxter, 1993). The main pathways through which the population living around coal-fired power plants are exposed to enhanced level of natural radionuclides are: inhalation during the passage of the plume, external exposure and inhalation and ingestion resulting from the radionuclides deposited on the ground (UNSCEAR, 1982). The phosphate rock is used as a source of phosphorous fertilizer. It contains trace amounts of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K, which are redistributed to the environment in the course of rock's industrial processing and use. This comes about through effluent discharges, the agricultural use of fertilizers and the utilization of by products and waste material for other purposes (UNSCEAR, 1982).

Analysis of the radionuclide continent of water, soil, food, rock, air and knowledge of the metabolic behavior of investigations are needed to obtain a clear understanding of the basic dynamics of radioactivity in the environment. The external gamma radiation exposure to the population changes due to the geology and geographical condition of the area and its associated radioactivity level in the soil (Linsalata, 1994). Many researchers have studied the radiation level in various parts of the word has been reported and the distribution of natural radionuclides in environmental matrices such as rocks and soil (Papp et al.,2002;Flues et al., 2002;Sivakumar et al., 2012; Özmen et al., 2014;Özden et al., 2013; Rangaswamy et al., 2015; Mehta et al., 2015; Prakash et al., 2017; Michelet al., 2019). A more extensive and systematic investigations are needed to obtain a clear understanding of the basic dynamics of radioactivity in the environment.

Literature shows that people residing around the thermal power plant in Udupi, have complained of health issues like respiratory problems, skin rashes and eye irritations due to contaminated air, soil and water and also low soil quality, poor yielding of crops, corrosion of utensils and poor quality of water because of fly ash that has significant heavy metal concentration (Adappa et al., 2017). So an extensive and systematic investigation is necessary understand to measure the activity concentrations of radionuclides in the regions around the thermal power plant, in Udupi district on south west coast of India. The Udupi district is situated in the coastal part of Karnataka state, along India's western coast of peninsula, with an area of 3575 sq Km. It lies between the geographic coordinates of 13º 04′ and 13º 59′ N latitude and 74° 35′ and 75° 12′ E longitude. This study region is also a part of industrial area as recognized by the Karnataka Industrial Areas Development Board. To understand the radionuclide dynamics and dose received from soil, rock, fly ash and vegetation samples in Udupi district of South Karnataka, systematic investigations were carried out and reported in the thesis.

Aim and Scope

A careful study on various aspects of environmental radioactivity from the literature shows that the radiation level varies from place to place and region to region. The concentration of natural as well as man-made radionuclides in natural samples such as soil, rocks and vegetation differs from one region to other. The literature data also indicate that the natural sources of radiation can be modified by industrial and technological activities, particularly the production of electricity from coal based thermal power station. It is also clear that the distribution and behavior of radionuclides in the environment is not fully understood. Furthermore this could be different for different environs. The studies, though conducted extensively, do not cover entirely all the different regions of the world. In this context, the investigation was undertaken in order to perform systematic studies on the radiation level, radionuclide distribution in the environment of Udupi district.

The present study aims to assess the concentration of ^{226}Ra, ^{232}Th, ^{40}K in the soil, rock, fly ash and vegetation samples in the environment matrices of Udupi district and nearby regions on south west cost of India. It is important to assess the radiation hazard arising due to use of this soil, rock and fly ash samples which could be used as building construction materials and which results in the internal and external exposure to the occupants. This baseline information is necessary in order to evaluate the distribution of

terrestrial radionuclide and radiation dose likely to be received by population inhabiting in that area. The ^{210}Po and ^{210}Pb in soil samples were analyzed using radiochemical deposition. The ^{210}Po causes greater biological damage to the human body due to it transfer through the aerosol attachment and through food chain. The measurement of radium and radon activity concentration in soil were carried out using the sealed can technique. The higher radon level in soil can be ingested or inhaled will result in exposure of human organs to radiation, primarily lungs. Therefore, soil samples from the study area were examined for the concentration of Radon. The internal dose to the human organs, such as lungs has been estimated. The results were compared with the data reported for other environs.

The variation in activity concentration of radionuclides is may be contributed by several factors in the time of formation of soil. Therefore, the effect of physico-chemical properties of radio elemental distribution has been examined by using standard protocols. This play a major role in determining the behavior of radionuclides present in it. In the present study, the behavior of minerals was analyzed with the radionuclides activity concentration.

The research study undertaken and presented in this thesis enrich the global data bank on natural radioactivity which are potentially important for the purpose of radiation risk assessment. The results discussed in the thesis could help to minimize the health risk associated with it by adopting preventive measures wherever felt necessary.

Methodology

- In the present study, using the energy compensated GM tube based Polimaster (PM1405) gamma ray survey meter was used to measure the ambient gamma dose rate in the region.
- The sampling locations were identified based on geology of individual locations. The soil, rock, fly-ash and vegetation samples were collected in the region following the EML standard procedures (EML, 1983).
- The collected samples were brought to laboratory for further processing. The samples were dried in air circulated oven and sieved through 250 micron mesh. The sieved samples were stored in 250 ml container to obtain secular equilibrium between radium-226 and its progeny.

- In the present study, using a NaI(Tl) detector based gamma spectrometry system to determine the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the soil, rock, fly-ash and vegetation samples. The spectrometer efficiency and energy was calibrated using the IAEA standard sources.

- The concentration of alpha active radionuclide ^{210}Po was estimated by radiochemical separation and subsequent deposition on a silver disc. The disc was then counted on both sides using a ZnS(Ag) alpha counter having an efficiency of about 30%. The activity of ^{210}Pb was estimated through ^{210}Po by allowing the ^{210}Po plated solution for a period of 12 months to build up the ^{210}Po from ^{210}Pb.

- The XRD and FTIR spectrometry was used in the present study to analyze the mineralogical composition of the environmental samples. The minerals were identified by comparing the transmittance spectra of the samples with standard values.

- The FESEM/EDS was used for surface imaging as well as the elemental composition of fly ash samples.

- Multivariate statistical analysis was used to find the interrelation among the parameters obtained from the soil samples. In the present investigation, the statistical software 'Statistical Program for the Social Science (SPSS)' was used for the statistical analysis and correlation studies.

The Thesis

The thesis is divided into five chapters. Chapter 1 includes introduction, which gives information on literature survey and aim and scope of the present investigation.

Chapter 2 deals with the details of the instruments used during the investigation. The experimental techniques are also discussed in this chapter. Details of the instruments, like Gamma survey meter called, gamma spectrometer with NaI(Tl) detector, alpha counting system, Solid state nuclear track detector such as LR-115, Etching bath, spark counter, XRD , FTIR and FE-SEM/EDS used in the present work and their salient features are also discussed in this chapter.

Chapter 3 gives details of sampling stations, collection of samples, sample processing, radiochemical methods adopted to determine the activity concentration of various radionuclides, radon exhalation and concentration measurement. The methods used to

calculate the activity concentration of radionuclides in the environmental matrices from the measured counts are discussed. The estimation of radiation hazards to the population of the region are discussed in this chapter.

The results obtained during the present investigation are presented and discussed in Chapter 4. The chapter deals with details of gamma absorbed dose in air, distribution of natural radionuclides in various environmental matrices, radiological parameters associated with radionuclides, in Udupi district. The calculated radiation hazards parameters are compared with recommended limit to assess the radiation exposure to the human population in the study area. This chapter also includes the dependence of physico-chemical parameters of soil with statistical approach. The relation between natural radionuclide and mineral are also included. Also, the mineralogical and elemental composition of fly ash particles were studied to understand the effect of these particles on the environment were discussed.

The important conclusions concluded during the investigation are presented in Chapter 5. Suggestions for future studies in this important field are also indicated.

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Research Guide Research Student

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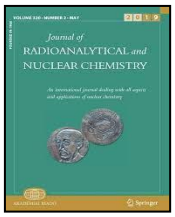
LIST OF PUBLICATIONS

Research articles published in Journals (Peer-Reviewed)

Part of the Thesis

[1] 

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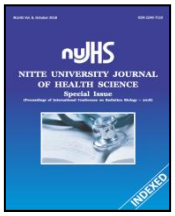
[3] 

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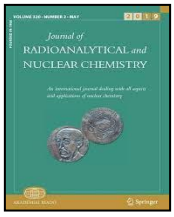
[7] 

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SCIE and SCOPUS having Impact Factor 0.636

Chethan, G., Sunil, K. C.,**Sandesh, A.,** & Narayana, Y. (2020). Determination of thermal conductivity of Areca husk fiber by Lee's disc method. *Research Journal of Chemistry and Environment*, 24(I), 17–21.

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